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The influence of dispositional cognitive reappraisal and expressive suppression on post-retrieval and standard extinction

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ABSTRACT

Individual differences in the ability to habitually regulate emotion may impact the efficacy of fear memory extinction. The aim of this study was to assess the relationship between dispositional cognitive reappraisal and expressive suppression with post-retrieval and standard extinction. Fear memory and extinction were measured with recovery of skin conductance responses. We also examined the relationship between a temporal feature of electrodermal responding (half-recovery time) and each of the emotion regulation strategies. University students (*N* = 80) underwent a three-day fear conditioning procedure using a within-subject design consisting of acquisition on day one, post-retrieval extinction and standard extinction on day two, and recovery test on day three. Individual difference data on self-reported levels of cognitive reappraisal, expressive suppression, trait anxiety, and depression were collected. We did not detect a relationship between the two emotion regulation strategies measured in this study and acquisition or extinction. We found however, that increased dispositional use of cognitive reappraisal was associated with lower spontaneous recovery to both the post-retrieval extinction and standard extinction stimulus after controlling for age, trait anxiety, and depression. There were no associations between expressive suppression and conditioned responses. We also observed patterns of faster dissipation of arousal for reappraisal and slower for suppression to the conditioned stimulus during extinction training, which may represent the unique influence of each emotion strategy on the regulation of fear. We conclude greater daily use of cognitive reappraisal, but not expressive suppression, associates with extinction retention after receiving both standard and post-retrieval extinction.

Keywords

Post-retrieval extinction; memory reconsolidation; electrodermal activity; cognitive reappraisal; expressive suppression; half-recovery time

1. Introduction

Fear acquisition and extinction are the procedures of fear conditioning in which an individual learns to express and inhibit responses to associative cues. Acquisition involves learning to predict stimuli that are paired with an aversive stimulus, whereas extinction requires inhibiting responses to these learned associations. Both processes are adaptive and allows individuals to learn from their environment to avoid and predict potential danger (Schiller & Delgado, 2010). Although learning to predict threat is crucial, an inability to successfully extinguish learned fears can lead to the continued expression of fear responses even under non-threatening conditions, such as in post-traumatic stress disorder (PTSD) (VanElzakker, Dahlgren, Davis, Dubois, & Shin, 2014). However, not all individuals develop PTSD after a traumatic event (Kessler et al., 2017), which may be explained by dispositional factors. One potential factor that can be advantageous for emotion driven learning is the type of habitual emotion regulation strategy employed by individuals. In particular, cognitive reappraisal and expressive suppression are often cited in the literature for their roles in modulating behavioural and neurological responses to negative stimuli.

Cognitive reappraisal and expressive suppression are two important types of emotion regulation strategies known to play a role in mental well-being (Franchow & Suchy, 2015; Ranney, Bruehlman-Senecal, & Ayduk, 2017) and fear circuitry disorders (Dryman & Heimberg, 2018; Khan et al., 2021). Cognitive reappraisal is an antecedent-focused strategy used to adjust the impact of an emotional event by changing one’s perspective of the event (Gross & John, 2003) (e.g., reappraising a potentially disastrous situation as a beneficial learning experience). In contrast, expressive suppression is a response-focused strategy that involves controlling how the emotion is behaviourally expressed when faced with an emotion eliciting event (Gross & John, 2003) (e.g., attempting to appear composed when feeling upset). Relative to suppression, reappraisal is known to be more effective in reducing negative affect in response to negative images (Bebko, Franconeri, Ochsner, & Chiao, 2011) and reduce physiological responses when exposed to stressors (Hofmann, Heering, Sawyer, & Asnaani, 2009). We consider the different underlying processes involved in each of the emotion regulation strategies which may affect extinction retention.

Cognitive reappraisal and expressive suppression appear to involve different memory and attention processes when regulating emotion. High habitual use of expressive suppression is linked with attentional bias and higher arousal to threat (Bardeen & Daniel, 2017). Research has also shown the use of expressive suppression has detrimental effects on memory due to the cognitive resources required for self-monitoring efforts to suppress emotion (Moore & Zoellner, 2012; Richards, Butler, & Gross, 2003; Richards & Gross, 2000; Szczygieł & Maruszewski, 2015). Unlike expressive suppression, cognitive reappraisal is associated with increased attention to threat-related stimuli (Bebko et al., 2011; Vanderhasselt, Remue, Ng, & De Raedt, 2014) and enhanced memory for emotional material (Wang, Chen, & Han, 2017). Theoretically, enhanced attention and memory to threat stimuli should be important for both acquisition and extinction. Additionally, the ability to exert top-down control of emotional expression may be a critical factor to augment fear extinction learning.

Cognitive reappraisal is associated with increased prefrontal activation coupled with decreased amygdala activity when processing negative stimuli, indicative of effective recruitment of necessary brain structures to cope with emotions (Drabant, McRae, Manuck, Hariri, & Gross, 2009). This finding is also supported by meta-analytic studies showing the active use of cognitive reappraisal to rely on a network of frontal regions to reduce activation in the amygdala during downregulation of negative affect to stimuli and fear conditioning (Buhle et al., 2014; Frank et al., 2014; Kohn et al., 2014). This may be beneficial for extinction, as the prefrontal cortex (PFC)-amygdala coupling is important for the early phase of post-retrieval extinction (Feng et al., 2016), and for the entire standard extinction procedure (Feng et al., 2016; Schiller et al., 2013). However, extinction learning and cognitive reappraisal appear to recruit different neural processes to inhibit cue-related responding in the amygdala (for review, see Schiller & Delgado, 2010). Of note, the ventromedial PFC (vmPFC) has been consistently discussed as an important structure in extinction and extinction recall (Schiller & Delgado, 2010), whereas the dorsolateral PFC (dlPFC) and other cognitive control regions are involved in cognitive reappraisal (Buhle et al., 2014). Suppression is also considered to rely on prefrontal regions to regulate emotions (Dorfel et al., 2014), but its effect on the amygdala appears to generate mixed findings (Stenberg, 2020). For expressive suppression, the recruitment of frontal structures may more strongly indicate inhibition of affect via behavioural control of emotional expression (e.g., prefrontal-parietal network) (Dörfel et al., 2014; Pan et al., 2018). As such, its effect on the amygdala may be limited, given that expressive suppression inhibits the behavioural rather than the subjective experience of affect. This may partly explain why cognitive reappraisal rather than expressive suppression, has been shown to link with stronger learning and retention of extinction (Hermann, Keck, & Stark, 2014).

Research on the effect of cognitive reappraisal on fear conditioning generally use instructed paradigms which involves training and instructing participants to use reappraisal when presented with negative stimuli. Studies of this nature demonstrate reductions in skin conductance responses to fear conditioned stimuli after training participants to use cognitive regulation (Raio, Orederu, Palazzolo, Shurick, & Phelps, 2013), and cognitive restructuring, a technique similar to cognitive reappraisal (Shurick et al., 2012). Reappraisal applied during extinction was also shown to reduce valence ratings to conditioned stimuli in women, indicating enhanced extinction (Blechert et al., 2015). These finding offer evidence for the role of real-time use of cognitive reappraisal in the effective regulation of associative aversive learning across a range of fear indices. However, it is also important to understand how dispositional or daily use of cognitive reappraisal affects fear conditioning.

Unlike with instructed paradigms, spontaneous reappraisal refers to the habitual use of cognitive reappraisal, such that it can be an automatic and unconscious process of emotion regulation in everyday life (Drabant et al., 2009). Based on this characterisation, it can be theorised individuals with high dispositional reappraisal can be more efficient in regulating emotion over individuals making conscious efforts to reappraise (i.e., instructed reappraisal), as the former is not constrained by the conscious processing required in the latter. In a study by Hermann and colleagues (2014), an aversive social conditioning paradigm was used to investigate the relationship between dispositional cognitive reappraisal with electrodermal, subjective and neuroimaging data. The authors used the scores from the reappraisal subset of the emotion regulation questionnaire to measure dispositional cognitive reappraisal. Participants underwent acquisition and extinction on day one and extinction recall on day two. Although the authors did not detect a conditioned skin conductance response across all phases of the experiment, it was found dispositional cognitive reappraisal was shown to associate with reduced acquisition, and stronger extinction and extinction recall across different measures of learning (neuroimaging, subjective ratings) (Hermann, Keck, & Stark, 2014). Together, the literature indicates that cognitive reappraisal, but not expressive suppression may be advantageous for emotion-driven learning. There is little known about the impact of the habitual use of emotion regulation strategies in fear conditioning, and much less for post-retrieval extinction, thus warranting investigation.

Building from the literature, the present research aims to investigate whether dispositional emotion regulation strategies, such as cognitive reappraisal and expressive suppression, may be associated with fear conditioning and in particular, spontaneous recovery after receiving post-retrieval extinction. The literature has largely focused on the aspects of the memory trace and methodological factors which impact the outcomes of post-retrieval extinction (Bjorkstrand et al., 2016; Bjorkstrand et al., 2015; Chen et al., 2021; Golkar, Bellander, Olsson, & Ohman, 2012; Hu et al., 2018; Junjiao et al., 2019; Kitamura, Johnston, Johnson, & Strodl, 2020; Li et al., 2017; Liu et al., 2014; Steinfurth et al., 2014; Thompson & Lipp, 2017; Warren et al., 2014; Yang, Jie, Li, Chen, & Zheng, 2019), for review on the post-retrieval extinction effect, see Kredlow et al. (2016). There is limited research on how individual differences affect post-retrieval extinction. Several studies have examined the effect of genetics (Agren, Furmark, Eriksson, & Fredrikson, 2012; Asthana et al., 2016; Klucken et al., 2016), age (Johnson & Casey, 2015), and anxiety (Kredlow, Orr, & Otto, 2018) on behavioural post-retrieval extinction. However, more research is required to understand what other individual difference factors affect the efficacy of post-retrieval extinction.

This study involved analysing additional individual difference data collected in a previous study using a three-day fear conditioning paradigm involving acquisition on day 1, post-retrieval extinction and standard extinction on day 2, and a spontaneous recovery and reinstatement test on day 3 (Kitamura et al., 2020). Fear responses were measured via skin conductance responses (SCR). Our investigation involved inspecting the associations between cognitive reappraisal and expressive suppression with conditioned responses (acquisition, reactivation, extinction, spontaneous recovery). Based on literature which show that reappraisal enhances attention, emotional memory, and reduces negative affect relative to suppression, we hypothesised that cognitive reappraisal would associate with less recovery, whereas expressive suppression would be related to greater recovery of fear. Our aim was to test the hypothesis after controlling for age, gender, and mood (anxiety and depression). Age and gender or hormonal contraception use were considered as relevant covariates due to their impact on skin conductance responses (Labar, Cook, Torpey, & Welsh-Bohmer, 2004) and extinction recall (Graham & Milad, 2013; White & Graham, 2016), respectively. It was also important to control for mood (trait anxiety, depression) due to their impact on fear conditioning (Dibbets, van den Broek, & Evers, 2015; Soeter & Kindt, 2013). Moreover, to ensure that any relationships observed between emotion regulation use and fear recovery are not due to the influence of mood. In addition, we also conducted exploratory analyses on the temporal dynamic of SCR by examining the influence of each emotion regulation strategy on the half-recovery time during extinction. Half-recovery time was chosen as our temporal feature of interest because it is considered to reflect the dissipation of an emotional response (Mednicksbeh, 1975; Newrith, Meux, & Taylor, 2006). As such, the half-recovery time may potentially be a useful index of effective emotion regulation. These analyses were conducted to expand knowledge on individual susceptibility and resilience to fear memory development and maintenance. An additional aim was to contribute to the continued efforts in identifying the boundary conditions for the application of post-retrieval extinction.

2. Method

2.1.Participants

Eighty undergraduate students from the Queensland University of Technology aged 18-48 years (*M* = 23.68 years, *SD* = 7.40 years) were recruited to take part in the study. G*Power 3.1.9.7 was used to estimate the required minimum sample size of 65 participants to detect a medium sized effect (*r* = 0.34) with a power of 0.80 and an alpha of 0.05 in running our correlational analyses. As we were unable to locate a study using the same variables, the effect size was estimated from a study which examined the association between a different individual difference measure (state anxiety) and recovery SCR (Kuhn, Mertens, & Lonsdorf, 2016). Recruitment was conducted via a university research recruitment website and billboard flyers. The exclusion criteria for recruitment were as follows: minors under the age of 18, pregnancy, implantable or external cardiac pacemakers, history of epileptic episodes and any diagnosed or known cardiac conditions such as cardiac arrest, myocardial infarction, and cardiac surgery. Upon recruitment, participants were interviewed regarding the use of any medication, tobacco cigarettes, alcohol, and drugs (in the past 12 hours prior to testing), health or mental conditions, period of menstrual cycle, and any form of barrier or hormonal contraception (HC) use. The use of medication and drug use were questioned to consider their impact on autonomic responses, whereas mental health conditions were questioned so that these factors could be considered in the interpretation of data. Some participants reported prior or current diagnoses for a depressive disorder (n = 1), an anxiety disorder (n = 4), or attention deficit hyperactivity disorder (ADHD) (n = 1) and those currently diagnosed verbally reported being on stable doses of medication at the time of testing. No physical health conditions or any drug use were reported. To include a wide range of SCR, we did not apply an acquisition and extinction criteria thereby using the entire sample (N = 80) from our previous study (Kitamura et al., 2020). However, for reasons including a system error (n = 1), participants not returning for day 2 (n = 1) and not returning for both days 2 and 3 (n = 3), the samples analysed varied for the three experimental days, day 1: acquisition (N = 80); day 2: extinction (N = 76); day 3: spontaneous recovery test (N = 75). Additionally, two participants aged 45 and 60 years did not take part in the experiment as these individuals did not demonstrate measurable SC responses during the initial baseline measurement. To examine the effect of gender, we created three groups consisting of men (n = 15), women who were HC users (n = 29), and naturally cycling women (n = 36). An even number of participants received either a yellow or blue CS1+ or CS2+ with a grey CS- (Kitamura et al., 2020). All participants were given a written consent form to sign and received either AUD $30 or psychology undergraduate students were awarded 5% course credit for participation. The study was approved by the QUT University Human Research Ethics Committee (1700000750). See table 1 for means and SD for individual difference measures.

"Insert Table 1 About Here"

2.2. Stimuli

2.2.1. Conditioned stimuli

Three different coloured 14x14cm squares (yellow, blue, grey) were used. The yellow or blue squares served as the conditioned stimulus (CS1+, CS2+) and the grey square was always the control stimulus (CS-). The CS's were displayed on a 22-inch computer monitor set at a resolution of 1920x1080 pixels. Each CS was presented for a 6-second duration with a random inter-trial interval (ITI) of 10, 11, 12 seconds. During the ITI, a blank screen was presented with a fixation cross in the centre of the screen (Schiller, Raio, & Phelps, 2012). The presentation of each stimulus (CS1+, CS2+, and CS-) were counterbalanced with no more than two presentations of each CS in succession. The trial sequencing was developed to ensure that each trial difference (CS1+ or CS2+ versus CS-) were no more than two trials apart. During acquisition, the 40% reinforcement group were presented with 6 unreinforced CS1+ and CS2+ with 4 reinforced presentations. In contrast, the 80% reinforcement group received 2 unreinforced and 8 reinforced trials for each of the CS+'s. For both groups, the CS- were presented 10 times without reinforcement. All reinforced trials were presented with a fixed CS-

US interval; US presented 5.8 seconds after CS+ onset. The different presentations of the CS-US contingency (40%, 80%) were only applied on day 1 during acquisition. On day 2 extinction, 11 CS's were presented for each coloured square including the reactivation CS for the CS1+. On day 3 test phase 1, 6 CS+'s (CS1+ and CS2+) and 7 CS- were presented. After the reinstatement shocks on test phase 2, 4 CS+'s (CS1+ and CS2+) and 5 CS- were presented to test reinstatement effects. The additional CS- were inserted in both test phases to disregard orienting responses and were excluded from the analyses.

2.2.2. Unconditioned stimulus

The 200ms mild shock was administered either using a 40% or 80% partial reinforcement schedule depending upon random group allocation (see Kitamura et al., 2020, for more detail). The shock was administered on both day 1 during acquisition and on day 3 during reinstatement (see Fig. 1). The shock intensity was selected by the participant and all participants in the present sample demonstrated SCR in response to the shock. The US duration was set to 200ms/50 pulses. The shock was delivered via the MLT116F GSR bipolar finger electrodes which were placed on the middle phalanges of the participant's index and middle finger of the right hand for 200ms per presentation. The maximum strength of the shock was set to 10mA and was delivered by the AD instruments Fe180 constant current stimulator. The delivery of the shock was programmed to run according to the script using E-Prime software and the signals were recorded using Lab Chart.

"Insert Figure 1 About Here"

2.3. Skin conductance responses

The fear response in this study was a measure of skin conductance response which was recorded using the PowerLab Data Acquisition device and GSR amplifier from ADInstruments. Each participant was connected via MLT116F GSR bipolar finger electrodes which were attached to the middle phalanges of the index and middle finger. The skin conductance responses were recorded on the Lab Chart software and down sampled to 100Hz prior to analysis.

2.3.1. SCR assessment and scoring

SCR data was exported from Lab Chart and analysed using excel manually. The minimum response criteria to consider a response as stimulus specific was 0.02 microsiemens (µS). Any responses that did not fulfil this criterion were recorded as 0 for no response. The largest waveform (> 0.02 µS) from base to peak was taken between the 0.5 to 6.0s time window after stimulus onset. This time window was selected so that the maximum stimulus specific response could be recorded, rather than restrict responses only to the first or second intervals (Pineles, Orr, & Orr, 2009). The trough was recorded between the 0.5-4.5s time frame and the peak was taken between the 0.5-6.0s time frame after the trough to ensure that the data is not contaminated by the shock on reinforced trials. To ensure the base to peak SC responses were captured during this time window, a visual inspection of the data for each participant was conducted. To assess fear conditioning, the differential responding was calculated. Each stimulus specific response was taken, then a difference score was calculated for the base to peak amplitude for each stimulus (CS1+, CS2+, CS-). To analyse differences in early and late phase of each experimental session, these difference scores were averaged and separated into the first and last half to form each phase (early, late). For the differential skin conductance responses, each stimulus difference score was taken to calculate the difference between stimuli for each trial presentation (CS1+ minus CS-, CS2+ minus CS-) and averaged for the first trial, last trial, and the phases (early, late) where necessary. Recovery of fear was indexed as the differential last trial of extinction versus the differential first trial of test phase 1 for spontaneous recovery. We also recorded the reactivation SCR (R-SCR) which was the skin conductance response during the memory retrieval trial. The R-SCR was a single trial response to the CS1+ (yellow or blue square). All scores were square root transformed prior to statistical analysis.

2.3.2. Temporal SCR

The temporal feature of interest was the half-recovery time (i.e., time from peak to 50% recovery of SCR amplitude) (see Fig. 2). For the purposes of this study, the half-recovery time was collected on day 2 extinction for all stimuli (CS1+, CS2+, CS-) for all 10 trials. As the CS's were not reinforced during extinction, the time window to record the temporal feature of SCR was extended until the next presentation of the CS (e.g., 16-18 seconds). The 10 trials were averaged for each stimulus to derive a total half-recovery score in seconds. The temporal value was logarithmically transformed prior to analysis.

"Insert Figure 2 About Here"

2.4. Unconditioned responses

The SCR to the shock stimulus was recorded by taking each raw base to peak difference and applying a square root transformation to normalise the distribution. Then the average of the normalised difference scores for each group were taken: 40% reinforcement group (4 trials) and 80% reinforcement group (8 trials) to form the mean unconditioned response for each participant. Each participant's trial-by-trial SCR to all stimuli (CS1+, CS2+, CS-) were square root transformed and divided by the respective participant's average unconditioned response to account for individual differences in shock response (Schiller et al., 2012).

2.5. Questionnaires

To assess the effect of emotion regulation on fear conditioning, four surveys were administered prior to acquisition on day 1. The surveys used measured emotion regulation use (cognitive reappraisal and expressive suppression), trait anxiety, and depression. The administration of the surveys was counterbalanced to minimise order effects.

The Emotion Regulation Questionnaire (ERQ) consists of 10 statements on the habitual use of cognitive reappraisal and expressive suppression. There are 6 items testing reappraisal and 4 items relating to the use of suppression. Responses are made on a 7-point Likert scale (1 = strongly disagree, 4 = neutral, 7 = strongly agree). Higher scores on each subset indicate increased disposition towards use of each emotion regulation strategy (Gross & John, 2003). Reliability coefficients (Cronbach's alpha) for the scale are 0.73 for suppression and 0.79 for the reappraisal subset (Gross & John, 2003; Melka, Lancaster, Bryant, & Rodriguez, 2011). For this study, we observed acceptable to good internal consistency for reappraisal ($\alpha = 0.83$) and suppression ($\alpha = 0.79$).

The State Trait Anxiety Inventory (STAI) contains 20 short statements relating to symptoms of trait anxiety in which participants can respond on a 4-point Likert scale based on how participants generally feel (1 = almost never, 2 = sometimes, 3 = often, 4 = almost always). It is a scale used to measure both clinical and community levels of trait anxiety. The internal reliability of this measure ranges from 0.89-0.92 in non-clinical samples (Balsamo et al., 2013;

Crawford, Cayley, Lovibond, Wilson, & Hartley, 2011; Scheier, Carver, & Bridges, 1994). The internal consistency for this measure was excellent (α = 0.93) in our study.

The Patient Health Questionnaire-9 (PHQ-9) is a clinical instrument developed to assess symptoms of clinical depression over the past two weeks before testing. There are 9 symptoms which can be rated on a 4-point Likert scale (0 = not at all, 1 = several days, 2 = more than half the days, 3 = nearly every day). Scores are categorised as per the following: minimal (0-4), mild (5-9), moderate (10-14), moderately severe (15-19), and severe (20-27). However, for the purposes of this study, we used the PHQ-9 as a continuous variable to assess correlations with SCR. The Cronbach's alpha coefficient demonstrated on this measure is between 0.87-0.89 within primary care and general population samples (Kocalevent, Hinz, & Brahler, 2013; Kroenke, Spitzer, & Williams, 2001). This instrument had good internal consistency in this study (α = 0.87).

2.6. *Sex and hormone status*

Hormonal contraception (HC) use and gender was determined prior to testing via a face-to-face interview. Participants were asked whether any form of birth control was used and if not, to report the particular phase of the menstrual cycle the participants at the time of testing was experiencing. All participants who were taking HC reported using combination monophasic oral contraceptives.

2.7. Procedure

Participants underwent fear acquisition on day 1, reactivation and extinction on day 2, a spontaneous recovery test, re-extinction, and reinstatement on day 3. Survey data and participant information was only collected on day 1. The contingency awareness test and valence rating was recorded on day 1 immediately after acquisition. The US expectancy rating was measured on day 2 following the reactivation cue.

2.7.1. Day 1: Acquisition

Participants were subjected to a differential fear conditioning in a well-lit temperature-controlled room where participants were seated in front of a computer screen. After the arrival of each participant, the participants were given a brief explanation on the study procedure and informed consent was provided. Participants were instructed to wash hands and dry thoroughly prior to attaching all electrodes. Once the participant had washed their hands and entered the room, the questionnaires (ERQ, STAI, PHQ-9) were administered. Upon completion of the surveys, participants were given a brief interview to collect information on participants regarding their age, sex, food, and coffee consumption in the past two hours, use of alcohol, drugs, cigarettes, and any medication in the past 12 hours, mental or physical conditions that are known or diagnosed, period of menstrual cycle, and any use of hormonal contraception. The time it took to complete the questionnaires and the interview were used to acclimatise the participant before attaching the electrodes. Upon the completion of the questionnaires, alcohol wipes were applied to the areas where the electrodes were to be attached before putting on the skin conductance and shock electrodes. Before recording the baseline, participants were instructed to breathe deeply and relax to assess responsivity of SCR. Once the participant had shown responsivity, the baseline for the SCR was obtained for 5 minutes. After the baseline period, the intensity of the shock was determined by asking the participant to select a level that was "incredibly annoying, yet not painful". The intensity of the US started at 0.5 milliamps (mA) and was increased by 0.5mA increments. Once the shock level was selected, the participants were rested for a period of five minutes to return skin conductance levels to baseline. Following this, the participants were instructed to refrain from moving throughout the procedure and fixate on the screen. The participants were given a partial CS-US contingency instruction by revealing that two out of the three squares would be followed by the shock some of the time, whereas the remaining square would never be followed by the shock. The program was preselected based on the experimental condition that the participant was randomly allocated to which commenced once the space bar was pressed. Upon the completion of the acquisition program, a contingency awareness test and threat rating was administered. Once complete, the participants were requested to remember the CS-US contingencies and thanked for participating.

2.7.2. Day 2: Reactivation and extinction

Upon the participants arrival, again the alcohol wipes were used to clean the areas of electrode placement. Once the SCR and shock electrodes were attached to each participant, a five-minute break was inserted to ensure the participant had sufficiently acclimatised to return body temperature to baseline. Prior to commencing the experimental program, the participants were instructed to remember the CS-US contingencies from the day before as has been done in prior studies (Kindt & Soeter, 2013; Soeter & Kindt, 2011; Thompson & Lipp, 2017) and to fixate on the screen and to refrain from moving. Participants were also informed that they may or may not receive a shock whilst verbally confirming the shock level and turning the shock stimulator on. When the participant was ready, the space bar was pressed by the experimenter to begin the experiment. The program began with a reactivation cue (CS1+) followed by the US expectancy test. Immediately after this, a 10-minute video (scenery nature video) had begun before progressing to the extinction phase. After the extinction phase, the participants were again thanked for participating and were asked to return the following day at the scheduled time.

2.7.3. Day 3: Test phase

The set-up procedure was identical to what was done on day 2 which began with cleaning areas of electrode placement, acclimatising, attaching all electrodes (SCR and shock electrodes), and providing the same instructions. This was followed by a re-extinction phase to assess spontaneous recovery of fear. Upon completion, the participants were thanked and if eligible, were given 5% course credit for participation or given AUD $30 in cash.

2.8. Statistical analysis

Statistical analyses were conducted on the Statistical Package for the Social Science (SPSS) version 26. As we had previously used two CS+'s (Kitamura et al., 2020), the acquisition and extinction SCR were averaged between the CS1+ (post-retrieval extinction) and CS2+ (standard extinction) stimulus. Additionally, as our prior study used two reinforcement rates as a between-groups factor, we conducted preliminary analyses via ANOVA to assess their effect on SCR so that reinforcement rate could be controlled for in the correlational analyses where appropriate. We also included hormone status in the ANOVA to ascertain whether it should be controlled for in the partial correlation analysis. We did not assess group differences or correlations for reinstatement due to our prior findings of a smaller effect and weaker associations with reinstatement return of fear (ROF) following a spontaneous recovery test (Kitamura et al., 2020) which may be due to interference when testing multiple indices of recovery (Haaker, Golkar, Hermans, & Lonsdorf, 2014). Additionally, all analyses were conducted with and without participants that reported a current or prior diagnosis for a mental disorder (n = 6). As the results did not change based on the current or prior mental disorder diagnosis or medication use status, the data reported include all samples.

2.8.1. Acquisition, extinction, and spontaneous recovery: Whole sample analysis

To determine if the entire sample demonstrated acquisition, extinction, and spontaneous recovery, a 2 x 2 x 3 mixed analysis of variance (ANOVA) was used with a Bonferroni adjustment, with phase as a repeated measures variable, reinforcement group (40%, 80%), and hormone status (male, naturally cycling women, HC women) as between-groups factors. Follow-up tests involved using t-tests to compare spontaneous recovery between the standard and post-retrieval extinction stimulus.

2.8.2. Bivariate and partial correlations between emotion regulation and SCR

Preliminary analyses for the correlations involved assessing the bivariate relationships between emotion regulation use (cognitive reappraisal, expressive suppression) with SCR for acquisition (average late phase differential SCR), R-SCR (single trial SCR to CS1+ stimulus during memory reactivation), extinction (average differential late phase of extinction), and spontaneous recovery for the post-retrieval extinction (CS1+) and standard extinction stimulus (CS2+) (recovery index). After identifying significant relationships, a partial correlation analysis was used to control for demographic and mood factors.

2.8.3. Comparison of spontaneous recovery to post-retrieval extinction and standard extinction in low and high cognitive reappraisers

To assess whether low and high cognitive reappraisers equally demonstrate recovery SCR to both the post-retrieval extinction (CS1+) and standard extinction (CS2+) stimulus, reappraisal scores were split into low and high groups based on the normative Australian population means (*M* = 29.00) (Preece, Becerra, Robinson, & Gross, 2020). This resulted in the two following groups for analysis: low reappraisal (*n* = 36; *M* = 24.77, *SD* = 4.47) and high reappraisal (*n* = 39; *M* = 35.00, *SD* = 3.76). To conduct the analysis, a 2 x 2 x 2 ANOVA was used with a Bonferroni adjustment with phase (last trial of extinction, first trial of test phase) and stimuli (CS1+, CS2+) as repeated-measure factors and group (low, high reappraisal) as a between-groups factor. Age, trait anxiety, and depression were included as covariates.

2.8.4. Partial correlations between emotion regulation and SCR half-recovery time

To examine whether dispositional cognitive reappraisal and expressive suppression influences the time it takes for SCR to dissipate when extinguishing fear, correlations were assessed between emotion regulation and half-recovery time during extinction. This was achieved via partial correlations to control for age and mood factors. The post-retrieval extinction and standard extinction stimuli (CS1+, CS2+) were averaged to form the conditioned stimulus (CS+). Both the CS+ and CS- half-recovery times were included in the analysis. Spearman's rho correlation was used due to breach of normality in the SCR, time feature and individual difference factors after transformation.

3. Results

3.1. Acquisition, extinction, and spontaneous recovery: Whole sample analysis

We first analysed the whole sample to determine if the entire sample demonstrated acquisition and extinction of conditioned responses. Note that this analysis differs from our previous study (Kitamura et al., 2020) due to the differences in sample size, as we did not apply the acquisition and extinction criteria for the present study. We found significantly greater differential SCR during the late phase of acquisition (*M* = 0.13, *SD* = 0.20), than the early phase of acquisition (*M* = 0.02, *SD* = 0.20), $F(1, 74) = 13.428$, $p < .001$, $\eta^2_p = .154$. For extinction, there was a significant decrease in differential SCR from the early phase of extinction (M = 0.10, SD = 0.19) when compared with the late phase of extinction (M = 0.04, SD = 0.13), $F(1, 69) = 4.531$, $p = .037$, $\eta^2_p = .062$. There was no effect of reinforcement rate on both acquisition, $F(1, 74) = .092$, $p = .763$, $\eta^2_p = .001$, and extinction, $F(1, 69) = .174$, $p = .678$, $\eta^2_p = .003$. There was also no effect of hormone status on acquisition, $F(2, 74) = .518$, $p = .598$, $\eta^2_p = .014$, and extinction, $F(2, 69) = .897$, $p = .412$, $\eta^2_p = .025$. These findings indicate that the entire sample demonstrated acquisition and extinction of conditioned responses.

We then inspected the spontaneous recovery of conditioned responses. The analyses indicated that there was a significant recovery for the CS2+ stimulus from the last trial of extinction (M = -0.08, SD = 0.33) to the first trial of test (M = 0.10, SD = 0.44), $F(1, 69) = 9.364$, $p = .003$, $\eta^2_p = .119$. In contrast, there was no recovery to the CS1+ stimulus indicated by a non-significant difference between the last trial of extinction (M = -0.04, SD = 0.33) to the first trial of test (M = -0.02, SD = 0.39), $F(1, 69) = .011$, $p = .918$, $\eta^2_p = .000$. Differences between the two stimuli showed significantly greater first trial differential SCR for the CS2+ than the CS1+ stimulus, $t(74) = 2.821$, $p = .006$, $d = 0.30$. There was also significantly greater recovery via the recovery index with greater SCR for the CS2+ than the CS1+ stimulus, $t(74) = 3.037$, $p = .003$, $d = 0.31$. There was no effect of reinforcement rate on the spontaneous recovery to both the CS1+ stimulus, $F(1, 69) = .136$, $p = .713$, $\eta^2_p = .002$, and CS2+ stimulus, $F(1, 69) = .610$, $p = .437$, $\eta^2_p = .009$. There was also no effect of hormone status on spontaneous recovery to both the CS1+ stimulus, $F(2, 69) = .258$, $p = .774$, $\eta^2_p = .007$, and CS2+ stimulus, $F(2, 69) = 2.622$, $p = .080$, $\eta^2_p = .071$. Overall, the analysis on the entire sample shows that the participants demonstrated recovery of conditioned responses only for the standard extinction (CS2+) and not to the post-retrieval extinction stimulus (CS1+). Refer to Fig. 3 for trial-by-trial SCR across all experimental phases.

3.2. Bivariate correlations between emotion regulation and SCR

Prior to inspecting partial correlations, we looked at the bivariate correlations between emotion regulation strategies and fear conditioning SCR. As shown in table 2, we found that cognitive reappraisal was negatively related to spontaneous recovery SCR (see Fig. 4). In particular, reappraisal associated with significantly less recovery to both the post-retrieval extinction stimulus (CS1+) and standard extinction stimulus (CS2+). Cognitive reappraisal was not related to SCR during acquisition, memory reactivation and extinction. We did not detect a relationship between expressive suppression and SCR across all experimental phases.

"Insert Table 2 About Here"

"Insert Figure 3 About Here"

3.3. Partial correlation: Emotion regulation and spontaneous recovery

We then assessed whether the correlation between cognitive reappraisal and spontaneous recovery SCR would remain after controlling for age, trait anxiety, and depression. The negative associations between cognitive reappraisal and SCR remained for all prior significant associations (CS1+ recovery index, CS2+ recovery index; see table 3). The findings indicate that after controlling for age, trait anxiety, and depression, a greater habitual use of cognitive reappraisal but not expressive suppression associated with less spontaneous recovery after receiving both post-retrieval extinction and standard extinction.

"Insert Table 3 About Here"

3.4. Comparison of spontaneous recovery to post-retrieval extinction and standard extinction in low and high cognitive reappraisers

To determine whether cognitive reappraisal affects spontaneous recovery SCR equally to the standard and post-retrieval extinction stimulus, we examined the effect of low and high reappraisal on the recovery index for each stimulus (CS1+, CS2+) while controlling for age, trait anxiety, and depression. We detected a significant interaction between cognitive reappraisal and phase, $F(1, 73) = 9.359$, $p = .003$, $\eta^2_p = .114$, which revealed significantly greater recovery from the last trial of extinction to the first trial of test phase for the low reappraisal group, $F(1, 73) = 12.108$, $p < .001$, $\eta^2_p = .142$, but not in the high reappraisal group, $F(1, 73) = .630$, $p = .430$, $\eta^2_p = .009$. We however did not find a significant interaction between cognitive reappraisal x stimuli, $F(1, 73) = .229$, $p = .634$, $\eta^2_p = .003$, or a cognitive reappraisal x phase x stimuli interaction, $F(1, 73) = .000$, $p = .990$, $\eta^2_p = .000$. Based on these findings, we conclude that equal recovery and non-recovery were evident across stimuli in low and high reappraisers, respectively.

3.5. Partial correlation: Emotion regulation and half-recovery time of SCR

For the exploratory analyses on the temporal feature of SCR, bivariate correlations were inspected to assess whether the emotion regulation strategies relate with extinction half-recovery time for the conditioned (CS+) and control stimulus (CS-) whilst controlling for age and mood. As shown in table 4, the analysis revealed that there was a significant negative association between cognitive reappraisal and half-recovery time for the conditioned stimulus (CS+). In contrast, expressive suppression was positively related with half-recovery time for the conditioned stimulus. Neither emotion regulation strategies were related with the control stimulus (CS-). There was no significant difference in half-recovery time between the CS1+ and CS2+ stimuli, $F(1, 71) = 3.020$, $p = .087$, $\eta^2_p = .041$. These findings indicate that greater habitual use of cognitive reappraisal associates with faster half-recovery time during extinction to the conditioned stimulus. In comparison, greater habitual use of expressive suppression relates with longer half-recovery time to the conditioned stimulus. However, both emotion regulation strategies were not related to the time in the dissipation of skin conductance responses to the control stimulus.

"Insert Table 4 About Here"

4. Discussion

The present study investigated whether self-reported habitual use of two emotion regulation strategies were associated with spontaneous recovery after post-retrieval and standard extinction. Based on prior research, which link the use of cognitive reappraisal with enhanced attention and memory, and the effective recruitment of neuronal structures to regulate emotion, we hypothesised that daily use of cognitive reappraisal would negatively associate with spontaneous recovery. We also predicted that the daily use of expressive suppression would positively relate to the recovery of conditioned responses due to evidence linking suppression with compromised memory and enhanced negative affect when processing emotional stimuli. The aim was to test these hypotheses whilst controlling for the effects of age, trait anxiety, and depression. We further looked at the influence of each emotion regulation strategy on the temporal feature of SCR half-recovery time to gain a better understanding of their impact on extinction learning and subsequent fear recovery. To the best of our knowledge, this study is the first to analyse these factors in a post-retrieval extinction study using a healthy adult sample.

Contrary to our hypothesis, we did not observe a relationship between expressive suppression and fear conditioning SCR across all experimental phases. However, we found that cognitive reappraisal was associated with reduced spontaneous recovery of the SCR. Specifically, reappraisal scores were negatively correlated with the SCR recovery index for both the post-retrieval and standard extinction stimulus. We then determined that after controlling for age, trait anxiety, and depression, these significant negative associations remained. We also found equal recovery and non-recovery after standard and post-retrieval extinction in low and high reappraisers, respectively. Our findings indicate that increased self-reported habitual use of cognitive reappraisal, but not expressive suppression relates with less spontaneous recovery following both standard and post-retrieval extinction. Additionally, these findings were not due to the influence of age, gender, anxiety, or depression.

The regular use of cognitive reappraisal may improve extinction outcomes via allocation of attention and memory to threat stimuli. Habitual reappraisers demonstrate enlarged pupillary dilation indicative of sustained attention in preparation for upcoming emotional stimuli (Vanderhasselt et al., 2014). Attention to emotional stimuli in reappraisers were not only shown to decrease negative affect (Bebko et al., 2011), but can increase the recall of memory. Wang and colleagues found that when compared with groups who engaged in expressive suppression or passive viewing, reappraisers outperformed all other groups on memory performance and regulation of emotional valence and arousal to both positive and negative stimuli (Wang et al., 2017). Wang and colleagues (2017) suggested that the cognitive reappraisal group directed more attention to the stimuli thereby enhancing the processing of emotional material, whereas the tendency for avoiding negative images in the suppression group resulted in the impairment of memory recall and recognition. As such, it appears that cognitive reappraisal can facilitate attentional and memory processes that may be advantageous for emotion-driven learning. In particular, the habitual use of cognitive reappraisal may promote standard and post-retrieval extinction mechanisms via the top-down emotional control mechanisms recruited during presentation of threat stimuli.

Use of cognitive reappraisal has been shown to engage prefrontal regions to exercise cognitive control of negative affect (Nelson, Fitzgerald, Klumpp, Shankman, & Phan, 2015). In fact, reappraisal success to down-regulate negative affect was related to an increased activation of the bilateral ventrolateral PFC and the decreased activity in the left amygdala in response to aversive images (Morawetz, Bode, Baudewig, & Heekeren, 2017). As such, the ability to successfully reappraise an emotional experience may be associated with increased PFC-amygdala coupling (Morawetz et al., 2017), which appears to be important in preventing ROF in both post-retrieval (Feng et al., 2016) and standard extinction (Feng et al., 2016; Schiller et al., 2013). Similar to these instructed conditions, dispositional reappraisal appears to associate with effective recruitment of cognitive control regions to downregulate responses to negative stimuli. In a study by Drabant and colleagues (2009), the authors examined neurological activations when processing negative facial expressions after measuring dispositional cognitive reappraisal. The study reported reduced activations in the amygdala amongst participants who reported frequent use of reappraisal. It was also found similar control-related PFC regions were activated as found in studies using instructed reappraisal, albeit weaker. This finding led to the conclusion that the daily use of reappraisal may result in neural efficiency requiring less effort on cortical resources than when under newly acquired conditions (Drabant et al., 2009). Considering this finding, we speculate that the participants in our study who scored higher on habitual cognitive reappraisal naturally applied this emotion regulation strategy throughout the fear conditioning experiment.

It would be important for future research to understand the impact of dispositional reappraisal on the retainment of extinction learning by further identifying the commonalities and differences in neuronal activation between reappraisal and extinction. A meta-analysis by Pico-Perez and colleagues (2019) examining the neural correlates of extinction and cognitive reappraisal found that regions specific to extinction reflected the active perceptual processing of affective stimuli. Cognitive reappraisal was distinct from extinction in the recruitment of a network of regions engaged in higher cognitive processing. The meta-analysis also identified shared regions between cognitive reappraisal and extinction (e.g., dorsal anterior cingulate and anterior insular cortex) with their activation reflecting self-regulation and affective stimuli processing (Picó-Pérez et al., 2019). Based on these findings, cognitive reappraisal and extinction appear to recruit the same regions to process affective stimuli and self-regulate emotional and behavioural impulses throughout fear conditioning. Whether the ability to effectively use cognitive reappraisal augments extinction learning or has its own distinct influence in memory updating is not clear. Nevertheless, the habitual use of cognitive reappraisal appears to be advantageous for preventing spontaneous recovery of skin conductance responses in standard extinction and post-retrieval extinction as indicated by the correlational analysis in this study.

To better understand how cognitive reappraisal and expressive suppression may affect fear recovery, we also conducted exploratory analyses to determine whether these emotion regulation strategies influence extinction learning. Specifically, it was of particular interest to assess whether cognitive reappraisal and expressive suppression would relate with how quickly an individual recovers from arousal during extinction learning. The analyses revealed reappraisal was negatively associated with half-recovery time for the conditioned stimulus, but not for the control stimulus. By contrast, expressive suppression was positively associated with half-recovery time to the conditioned stimulus and not to the control stimulus. These findings indicate that the emotion regulation strategies tend to associate with the half-recovery SCR in opposing patterns, with faster recovery for reappraisal and slower recovery for suppression. Half-recovery time of autonomic responses is considered to reflect the dissipation of an emotional response (Newrith et al., 2006), such as fear (Mednicksbeh, 1975), and may be indicative of prefrontal cortex activity to regulate the time course of affective responding (Davidson, 1998). With this in mind, habitual cognitive reappraisers may be more effective in regulating autonomic responses to threat more quickly than habitual expressive suppressors when learning to extinguish previously conditioned fear memory.

4.1.Limitations and future directions

There were potential limitations that need to be addressed. First, the study used self-report measures for cognitive reappraisal and expressive suppression. Whilst this method was sufficient in addressing the research question, instructing participants to use specific emotion regulation strategies during post-retrieval extinction could be an avenue for future research (Graham, Ash, & Den, 2017; Olatunji, Berg, & Zhao, 2017). Real time use of cognitive reappraisal and expressive suppression coupled with neuroimaging may capture the underlying processes involved in memory retrieval and the recovery of conditioned responses for each of the emotion regulation strategies employed. Additionally, it is worth investigating the effect of the different tactics of cognitive reappraisal on post-retrieval extinction, for example, reinterpretation and distancing or up-regulation and down-regulation of fear. There appears to be differences in the lasting reductions of negative affect to aversive stimuli between reinterpretation and distancing (Hermann et al., 2020). Up-regulation and down-regulation was also shown to differentially impact subjective ratings, physiological responses, and neurological activity to aversive stimuli (Holland & Kensinger, 2013; Wiemer, Rauner, Stegmann, & Pauli, 2021). Second, as we did not determine if a particular emotion regulation strategy was used during the fear conditioning procedure, we cannot be certain if these strategies were actively used. In future, research of this nature should include a post-experiment assessment of the type of emotion regulation strategy used, if any. Third, we did not measure state anxiety in our study which may have had an influence on skin conductance responses as found in a previous study (Kuhn et al., 2016), for review, see Lonsdorf et al. (2017). Moreover, although we had attempted to control of trait anxiety, we acknowledge the trait version of the STAI measure may measure non-specific negative affectivity as opposed to trait anxiety, as found in a meta-analytic study (Knowles & Olatunji, 2020). Fourth, although we attempted to control for the effect of sex and hormones, we were not able to group the women based on estradiol levels, which are known to promote extinction recall in naturally cycling women (Graham & Milad, 2013; Milad et al., 2010; Zeidan et al., 2011). Future research should examine whether levels of circulating endogenous estradiol impact post-retrieval extinction. Last, our data for HC use represents women who use combination monophasic oral contraceptives, which should be considered in the interpretation of the findings.

4.2. Clinical implications

The results of this study show dispositional cognitive reappraisal may function as a protective individual difference factor that could be beneficial for extinction training, and by extension, exposure therapy. This may be due to the ability of habitual reappraisers to spontaneously regulate emotion to negative cues in the environment. If this is likely, it may be important to identify individuals with lower dispositional reappraisal so that cognitive reappraisal training can be provided prior to exposure therapy. However, more research is required to understand the role of dispositional reappraisal in extinction and exposure therapy among both healthy and clinical samples.

5. Conclusion

In summary, the study investigated whether individual differences in the daily use of emotion regulation, namely cognitive reappraisal, and expressive suppression, were associated with spontaneous recovery SCR after receiving standard and post-retrieval extinction. Our aim was to explore this whilst controlling for age, gender, trait anxiety, and depression, which are factors known to relate to fear conditioning. We found that after controlling for age, trait anxiety, and depression, dispositional cognitive reappraisal was negatively associated with spontaneous recovery to both the standard and post-retrieval extinction stimulus. By contrast, dispositional expressive suppression was not associated with spontaneous recovery. It was also shown that reappraisal was associated with faster half-recovery of autonomic responding whereas suppression related with longer half-recovery times. Together, we conclude that based on our sample, the habitual use of cognitive reappraisal, but not expressive suppression, may be an individual difference factor that could be beneficial for both post-retrieval extinction and standard extinction. These findings are novel, in that this study is the first to show support for the role of dispositional cognitive reappraisal in enhancing the behavioural post-retrieval extinction paradigm. Note however that we cannot conclude the direction of the association, such that an individual's broad capacity to regulate emotion for example, via both implicit (i.e., extinction learning) and explicit processes (i.e., cognitive reappraisal) may influence the ability to extinguish and prevent recovery of fear. More research is required to distinguish the underlying processes involved in extinction learning, and for instructed and habitual cognitive reappraisal. To conclude, the present study provides further insight into the boundary conditions of post-retrieval extinction, highlighting the role that emotion regulation may play in contributing to the efficacy of treating fear memory disorders.

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Author contributions

The study was designed and analysed by H.K. Conducted experiments: H.K. The manuscript was written by H.K., & E.S. Contributed to and edited the manuscript: E.S., P.J., L.J. Supervised the project: E.S., P.J., L.J. All authors reviewed the manuscript.

Competing interests

The authors declare no competing interests.

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Table 1
Descriptive Data for Individual Difference Measures

	Emotion Regulation and Mood Scores (*N* = 80)		
	M	*SD*	Range
Trait anxiety	46.20	4.23	36-55
Depression	8.21	5.57	0-25
Cognitive reappraisal	29.95	6.53	11-42
Expressive suppression	14.13	5.60	4-27

Note: The data represents raw scores. Measures used: trait anxiety (STAI), depression (PHQ-9), cognitive reappraisal (ERQ-R), expressive suppression (ERQ-S).

Table 2

Bivariate Correlations between Emotion Regulation and Skin Conductance Responses

	(1)	(2)	(3)	(4)	(5)	(6)
(1) Acquisition						
(2) R-SCR	.254*					
(3) Extinction	.076	.034				
(4) PRE index	-.026	.083	-.351**			
(5) SE index	-.059	.047	-.262*	.526***		
(6) Reappraisal	.009	-.076	-.068	-.341**	-.282*	
(7) Suppression	-.025	-.001	.059	-.042	.137	-.078

Note: Coefficients represent Spearman's Rho correlations of data for total sample size (N = 75-80). Acquisition (average differential SCR during the late phase of acquisition), R-SCR (single trial CS1+ SCR during memory retrieval), Extinction (average differential late phase SCR during extinction), PRE index (CS1+ differential last trial of extinction vs. differential first trial of test phase 1), SE index (CS2+ differential last trial of extinction vs. differential first trial of test phase 1), reappraisal (ERQ: cognitive reappraisal), suppression (ERQ: expressive suppression). * indicates $p < .05$. ** indicates $p < .01$. *** indicates $p < .001$.

Table 3

Partial Correlations between Emotion Regulation and Spontaneous Recovery

	Post-Retrieval Extinction (CS1+)	Standard Extinction (CS2+)
	Recovery index	
Cognitive reappraisal	-.257*	-.285*
Expressive suppression	-.058	.126

Note: Coefficients represent Spearman's Rho correlations of data for total sample size (N = 75). Recovery index (differential last trial of extinction vs. differential first trial of test phase 1 for spontaneous recovery). Age, trait anxiety, and depression were included as covariates. * indicates $p < .05$. ** indicates $p < .01$. *** indicates $p < .001$

Table 4

Partial Correlations between Emotion Regulation and Half-Recovery SCR during Extinction

	(1)	(2)	(3)
(1) CS+ half-recovery time			
(2) CS- half-recovery time	.312*		
(3) Reappraisal	-.379**	-.165	
(4) Suppression	.332**	.008	-.007

Note: Coefficients represent Spearman's Rho correlations of data for total sample size ($N = 75$). CS+ (average CS1+ and CS2+), CS- (control stimulus), half-recovery time (time from peak to 50% recovery of SCR amplitude). Time data in seconds. Age, trait anxiety, and depression were included as covariates. * indicates $p < .05$. ** indicates $p < .01$. *** indicates $p < .001$.

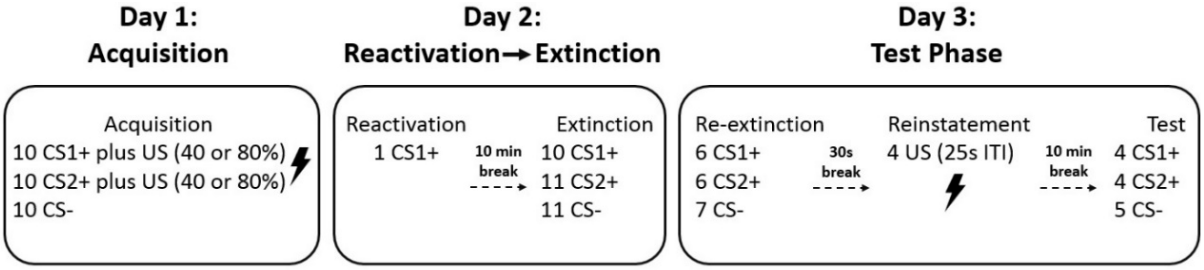

Fig. 1. Experimental design. On day 1 acquisition, participants were subjected to ten presentations of each stimulus (within-groups) at either a 40% or an 80% reinforcement schedule (between-groups). On day 2, only the CS1+ was reactivated so that one of the stimuli that was paired with the shock during acquisition would undergo post-retrieval extinction (CS1+), whereas the other, standard extinction (CS2+). After memory reactivation, all stimuli were presented without reinforcement to extinguish conditioned responses. On day 3, two test phases were inserted to test recovery of conditioned responses; spontaneous recovery 24 hours after extinction followed by reinstatement after presenting four unsignalled shocks.

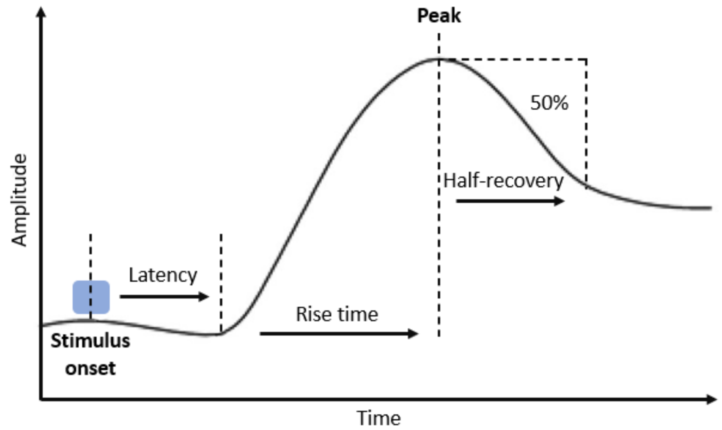

Fig. 2. Temporal features of skin conductance responses (SCR). Half-recovery was determined by measuring the time it took for the SCR to return to half the value of the peak (50%).

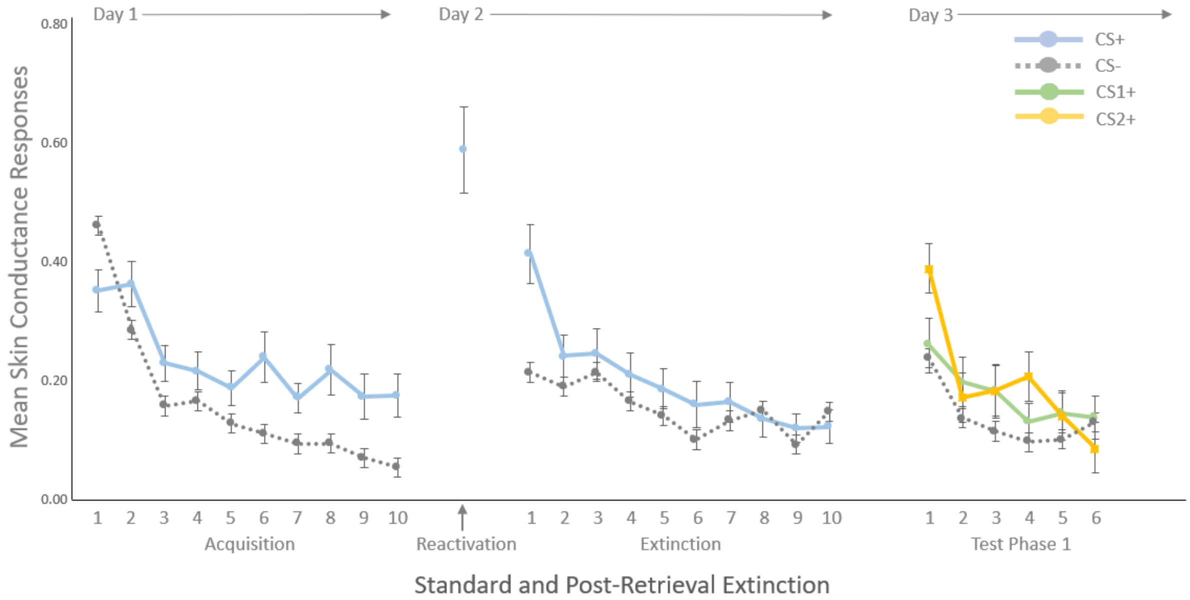

Fig. 3. Mean skin conductance responses across all experimental days (*N* = 75-80). Skin conductance responses to the post-retrieval extinction stimulus (CS1+) and standard extinction stimulus (CS2+) were averaged for acquisition and extinction to form the CS+. For the spontaneous recovery test (test phase 1), the CS1+ and CS2+ stimuli are presented separately. The data shows acquisition and extinction of conditioned responses. Spontaneous recovery was only detected for the CS2+ stimulus and not for the CS1+ stimulus. Error bars represent the standard error.

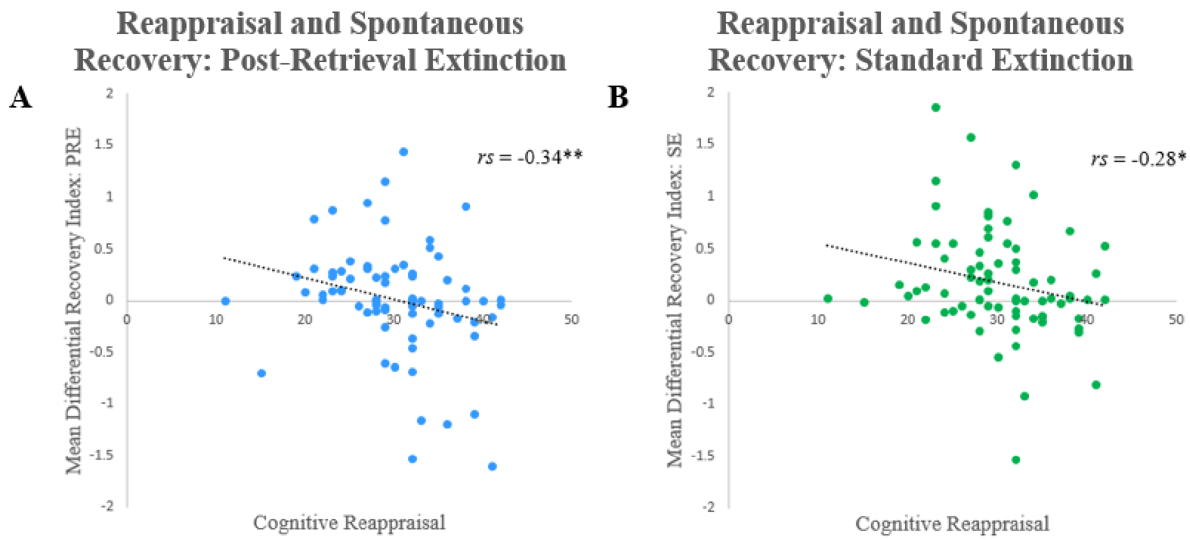

Fig. 4. Bivariate correlations between cognitive reappraisal and spontaneous recovery. (A) Correlation between cognitive reappraisal and the mean differential first trial SCR during spontaneous recovery test for post-retrieval extinction stimulus. (B) Correlation between cognitive reappraisal and the mean differential recovery index SCR during spontaneous recovery test for post-retrieval extinction stimulus. (C) Correlation between cognitive reappraisal and the mean differential first trial SCR during spontaneous recovery test for standard extinction stimulus. (D) Correlation between cognitive reappraisal and the mean differential recovery index SCR during spontaneous recovery test for standard extinction stimulus. * indicates $p < .05$. ** indicates $p < .01$. *** indicates $p < .001$.